The Role of Fluid Mud in Sediment Transport Processes Along a Muddy Coast

Gail C.Kineke
Dept of Geology and Geophysics
Boston College
Chestnut Hill, MA 02467
phone: 617-552-3655 fax: 617-552-2462 email: kinekeg@bc.edu

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LONG-TERM GOALS

The long-term goals of this study are to evaluate the role of high concentration sediment suspensions (fluid mud) in sediment transport processes along muddy coastlines. This requires an understanding of the formation and dynamic behavior of fluid muds, as well as the effects on attenuation of surface waves as they approach the shoreline.

OBJECTIVES

The motivation for this study comes from the acknowledgement that work done on sandy beaches is not directly transferable to muddy coasts, and the role of fluid mud is critical to large-scale beach changes on muddy coasts. This study addresses the following objectives:

1. to examine the formation of fluid mud on the inner shelf as the result of a) trapping due to convergence of bottom flows and enhanced settling at a salinity front, or b) a resuspension process due to surface wave activity;

2. to test the concept of a critical bearing capacity for a flow, based on results of Trowbridge and Kineke (1994); and

3. to document the attenuation of wave energy over an inner shelf with fluid muds and relate that to areas of shoreline accretion and erosion.

APPROACH

The study area is the shallow shelf (< 20 m water depth) from Atchafalaya Bay to ~ 100 km west along the western Louisiana coast. Spatial surveys consisting of a series of shore-normal transects have been repeated during different river discharge conditions to define the thickness and extent of fluid muds in relation to water properties (extent of freshwater plume and nearshore mudstream). An instrumented profiling tripod capable of measuring flow and fluid characteristics (Sternberg, et al., 1991) and a second, hand-deployable profiler (CTD plus optical backscatterance sensor) for shallow water work have been used. The profiling tripod has been used for spatial surveys (shore normal transects throughout the study area), as well as for tidal and longer time series while the ship is at anchor. The hand-deployable profiler is used off a small boat in water shallower than approximately 5 m. In

addition, the small boat is equipped with a dual high frequency echo sounder and differential GPS for mapping thickness and extent of nearshore fluid muds and unconsolidated bottom sediments.

Anchor station time series have been done using the profiling tripod to determine temporal variability and transport on tidal time scales. An array of three pressure sensors were deployed at depths of 16, 11, and 2 m, for three weeks in March and April 1999 to obtain time-series of wave characteristics through events of cold front passages, and to evaluate attenuation of wave energy across the shallow shelf.

Work continues on a prototype instrument to document vertical changes in differential pressure, and thus changes in fluid density, from within the mud bed to ~1.5 m above the bed. This will document changes in fluid mud thickness with passage of gravity waves, as well as the appearance of fluid mud due to settling.

WORK COMPLETED

Four cruises have been completed aboard the R/V Pelican: October 1997-low river discharge, March 1998 and 1999 -rising river discharge, high wind activity, and April 1998-high river discharge, diminishing wind activity.

Data collected on these cruises include hydrographic/suspended sediment surveys of 45 stations along seven shore-normal transects, time series measurements of 12-36 hours at several locations, shallow water surveys with the echosounder and CTD profiler, and coastal characterization. Wave sensors have been deployed in a cross-shelf array for a three-week time series. A prototype differential pressure staff is still under development.

RESULTS

Addressing our original objectives, it is apparent that high concentration sediment suspensions are ephemeral on this shallow shelf, dominated by rapid clearing of the water column after a wave event, typically associated with cold front passage. While resuspension due to waves appears to be critical to seed the water column with sediment, the high concentration suspensions form as the result of rapid settling rather than through fluidization of the seabed. These high concentration suspensions are on the order of a few g/l concentration, thus are somewhat borderline for classifying them as fluid muds, which typically have concentrations > 10 g/l.

Results to date focus on four general areas: 1) large scale distribution of the freshwater and sediment plumes; 2) cross-shelf attenutation of wave energy; 3) water column and suspended sediment response to the passage of cold fronts; and 4) coastal characterization.

The large scale surveys show little relation between the freshwater plume and the surficial sediment concentrations. Sediments are deposited close to shore during high river discharge, likely in a seasonal deposit, and are then reworked throughout the year with most transport onshore and to the west, mostly during December through April (Allsion et al. in press).

Time series measurements of wave characteristics at three cross-shelf locations show significant reduction in wave energy as the waves approach the shore, as much as 60-90 % over a distance of 24 - 34 km, with water depths varying from 16 m to 2 m. A friction factor two orders of magnitude greater than that suggested for a smooth bed (Dean and Dalrymple, 1981) is necessary to accomplish the observed reduction in wave amplitude from offshore deep water measurements to our observations intermediate and shallow water. This could be indicative of the influence of fluid mud or an represent the role of fluid

Figure 1 shows a time series of wind, air temperature, and water column conditions over a period of 8 days in March 1999. The water column observations were made at four anchor stations, progressively closer to Atchafalaya Bay. The time series demonstrate the rapid breakdown of salinity stratification and mixing of suspended sediment with the increase in wave speed and each frontal passage. Bottom concentrations > 1 g/l were persistent throughout the observation period, suggesting a pool of easily resuspendable sediment with the onset of each event.

An initial survey, or coastal characterization, has been completed for an ~ 18 km stretch of coast west of Atchafalaya Bay. Areas of mud and marsh alternate with sandy beach stretches. Dual frequency echo sounding records along offshore transects often indicate a wedge of unconsolidated sediment up to 0.75 m thick in shallow water (1-4.5 m water depth). These records are being analyzed to determine whether areas marsh areas are correlated with the presence of these mud wedges offshore. This could suggest the presence of the mud wedge diminishes wave activity reaching the coast, thus allowing development of marsh on an exposed coastline.

IMPACT/APPLICATIONS

A tremendous amount of research on coastal processes and sediment transport has occurred on sandy beaches; however, muddy coasts are quite common worldwide, especially close to large rivers, and have received relatively little attention by comparison. Wave attenuation is of primary significance for mitigation of shoreline erosion and coastal flooding, and wave attenuation on a muddy coast is directly linked to the characteristics and consolidation state of the muddy substrate, unlike sandy shorelines. In the presence of high concentration sediment suspensions, waves will progressively attenuate as they travel landward, resulting in decreasing boundary shear stresses close to shore, the opposite of what occurs on sandy coasts. Thus, the processes important on sandy beaches are not directly transferable to muddy coasts. The amount of field research done on wave/muddy coast interactions is severely lacking, although a great deal of effort has been done in laboratory flumes and theoretical studies. The field study in progress will provide essential observations for evaluation of the role of fluid muds in sediment transport and our ability to model the effects of wave-mud interaction.

TRANSITIONS

See Related Projects below.

RELATED PROJECTS

Sediment Trapping and Transport in Estuaries, Southeastern US, National Science Foundation CAREER Development Program, Kineke PI. This project began in September 1997 and is investigating sediment transport and trapping mechanisms in three estuaries in the southeastern United States

Sediment Dispersal from Vertically Divergent Plumes on a Mountainous Collision Margin: a New Paradigm for Continental Margin Sedimentation; National Science Foundation, Kineke co-PI. In part, this project examines formation mechanisms for high concentrations suspensions.

Collaboration with Dr. Miguel Goñi, an organic geochemist (University of South Carolina), began in March 1997. He has been funded by the National Science Foundation to investigate the terrigenous inputs of organic matter to sediments from deeper locations in the Gulf of Mexico. We have coordinated our field efforts and are sharing results allowing for an exciting interdisciplinary component to the ongoing study by analyzing the fate of terrestrial organic matter in marine sediments.

Dr. Brent McKee (Tulane University) has ongoing research in the Gulf of Mexico and the Mississippi and Atchafalaya estuaries (state and federal funding), in part to investigate partitioning and exchange of uranium and thorium isotopes in this three component system. The high concentration suspensions are a critical link between seabed and water column chemical exchange.

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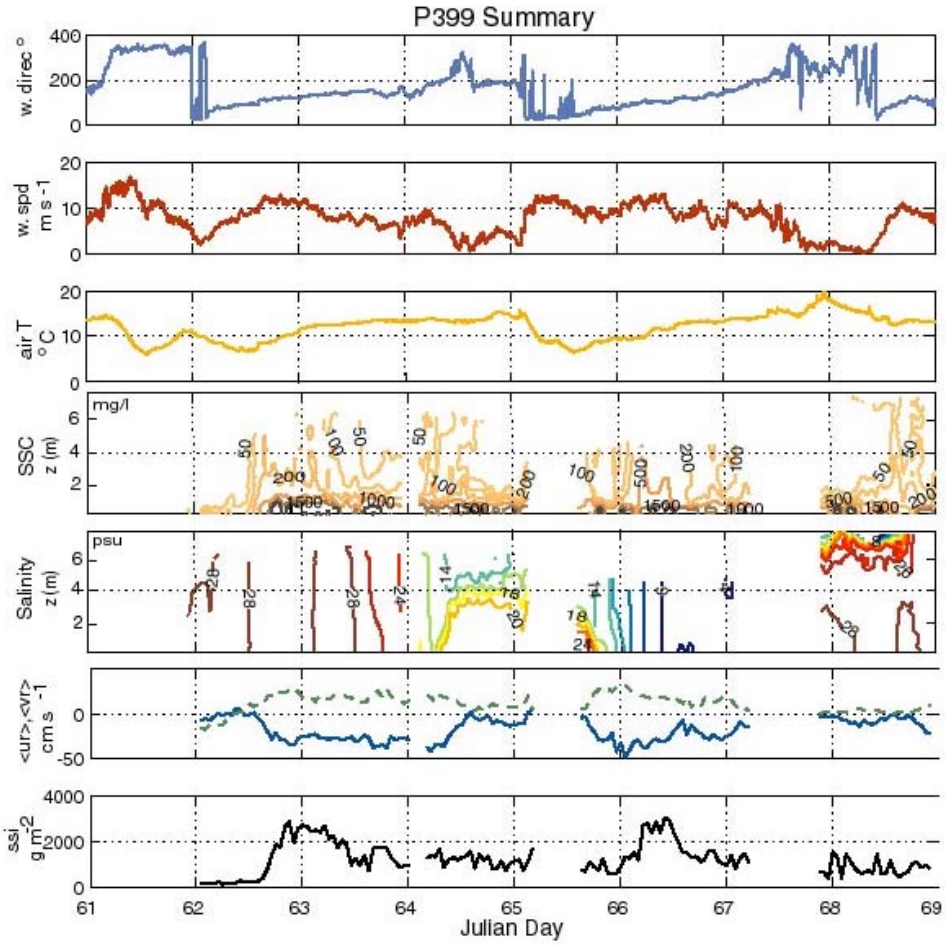

Figure 1.Time series of wind direction and speed, air temperature, suspended sediment concentration and salinity as a function of depth,depth-averaged along- (solid) and across- (dashed) shore velocity, and suspended sediment inventory at four locations on the shallow shelf. The time series shows several cold front passages with cycles of increasing/decreasing wind speeds accompanied by rapid breakdown and re-establishment of stratification in terms of both salinity and suspended sediment concentration. Fluxes are consistently onshore and to the west after the onset of the first event (JD 62.5). Bottom concentrations of ~ 1 g/l or greater were present at all locations throughout the observations, indicating a pool of easily resuspendible sediment that was also effective at attenuating wave energy close to shore.